REMARKS

For convenience in discussing applicants' response to the Action, the headings in the Action are used below. Prior to responding to the Action, applicants note that claim 2 has been amended to include the limitation of claim 17 and claim 17 has been canceled. I.e., amended claim 2 limits the binder of the active material layer of the negative electrode for a rechargeable lithium battery of the present invention to a polyimide binder.

Double Patenting

The Office has maintained the provisional double patenting rejections of claims 2-8, 11, 13-15, 17, 20-22 over claims of copending Application Nos. 10/363,039 and 10/673,348. The Office has not repeated the obviousness-type double patenting rejection over the claims of application No. 11/001,192 that was made in prior actions.

Applicants again request that these rejections be held in abeyance pending the determination of allowable subject matter in the present application or one of the related applications.

Specification

The disclosure is again objected to because the Office believes that it is not clear how the binder α1 differs from binder β1 and how the binder α2 differs from α3.

Applicants do not understand the objection to the specification. It is clear from the data in Tables 2 and 6 how the properties of the polyimide binders $\alpha 1$, $\beta 1$, $\alpha 2$ and $\alpha 3$ differ from each other. Nothing further is believed to be required.

If the Office maintains the objection to the specification, it is respectfully requested to explain what criterion are used by the Office to object to a specification. I.e., when is the specification of a patent application objectionable and when is it not objectionable.

The Office states that it is unclear how the different properties of the binders were obtained. Why is this a basis for objecting to the specification? Lack of clarity of a specification is an issue relating to enablement under the first paragraph of 35 U.S.C. § 112.

Removal of the objection to the specification is believed to be in order and is respectfully requested.

Claim Rejections - 35 USC § 112

Claims 2-8, 13-15, 17, 20-22 are again rejected under 35 U.S.C. 112, first paragraph, for lack of enablement. The Office's position is that it would require undue experimentation for a person of ordinary skill in the art to determine binders that have the properties recited in claim 2. More specifically, as explained

by the Office on page 11 of the Action, "the Examiner's position is that person of ordinary skill in the art would not be able to make the invention without the specifics of the polyamic acids and polyimides [used in the experiments in the present application]."

The issue raised under the enablement requirement of the first paragraph of 35 U.S.C. § 112, as explained in the Action, is whether the specification teaches a person skilled in the art to make and use the claimed invention without undue experimentation. The claimed invention in the present application, according to the claims as amended herein, is a negative electrode for a rechargeable lithium battery which includes a conductive metal foil current collector and an active material layer provided on a surface of the current collector and which comprises a polyimide binder and particles of active material containing silicon and/or a silicon alloy. The electrode is characterized in that the current collector has mechanical properties of at least 80 N/mm^2 tensile strength, at least 30 N/mm^2 proportional limit, at least 1.0 % elongation at break and at least 0.03 % elastic elongation limit and the polyimide binder has mechanical properties of at least 50 N/mm^2 tensile strength, at least 10 % elongation at break, at least 2.5×10^{-3} J/mm^3 strain energy density and up to 10,000 N/mm^2 elastic modulus. Applicants have discovered that a binder

having the properties recited in the claims can accommodate a high stress applied thereto as a result of volumetric expansion and shrinkage of the active material particles of the active material layer, and can prevents breakage of the binder during a charge-discharge reaction. The binder having the required properties is itself not novel.

Theefore, the specific issue raised by the instant rejection under the first paragraph of 35 U.S.C. § 112 is whether a person of ordinary skill in the art could determine or obtain polyimides useful as the binder in the active material layer of the negative electrode of the present invention, i.e., polyimides having the properties recited in the claims, without undue experimentation.

Applicants respectfully submit that polyimides, polyamic acids and techniques for preparing polyimides from polyamic acids or techniques for preparing polyimides according to other procedures are so well known and have been known for such a long time that a person of ordinary skill in the art could make or otherwise obtain suitable polyimides without experimentation or, at least, without excessive experimentation. Moreover, suitable polyimides are also commercially available.

For the same reasons, the specifics of the polyamic acids that were used in the experiments in the present application are not

required because these are not the only polyimides that can be used to practice the invention. In this regard, it is noted that the Office appears to believe that suitable polyimides can only be obtained by the treatment conditions used in the experiments in the examples in the present application or that only the specific polyimides used in these experiments can be used to practice the present invention. However, such belief is not correct and the Office has not identified any teaching in the specification or in the prior art to support such belief.

As examples of evidence of the fact that polyimides are well-known in the art and that are suitable for use in the present invention can be determined or obtained without undue experimentation, applicants note the term "polyimides" appears in the title of 318 United States patents. The term "polyimide" appears in the title of 1336 United States patents. The terms "polyimide(s)", "binder", "lithium" and "battery" developed 25,100 "hits" in a Google search conducted October 9, 2007. The terms "polyimide", "binders", "lithium" and "battery" developed 31,700 "hits". The terms "polyimide", "binders", "lithium" and "batteries" developed 37,800 "hits".

Applicants are also submitting herewith a document and English translation of pertinent portions thereof identifying

characteristics of commercially available binders. The mechanical properties of the polyimide binder recited in claim 2 of the present application correspond to the following items listed in Table 4.1-2:

- Tensile Strength: Tensile Strength (25°C);
- Elongation at Break: Coefficient of Extension (25°C) and
- Elastic Modulus: Coefficient of Elasticity (25°C).

The relationship between the units kg/mm² and N/mm² is 9.80665 kg/mm² = N/mm².

Referring to Table 4.1-2 (and converting to the relevant units), it is seen that the mechanical properties of "Upilex R" and "Upilex S" of Ube Machinery are as follows:

	Upilex R	Upilex S
Tensile Strength (N/mm²)	245	392
Elongation at Break (%)	130	30
Elastic Modulus (N/mm²)	3724	8820

These properties correspond closely to those of binders α1 and β1 in the experiments in the present application. The enclosed information is evidence of the commercial availability of suitable polyimide binders.

For the above reasons applicants submit that polyimide binders suitable for use in the present invention can be obtained without undue experimentation and that the application complies with the requirements of 35 U.S.C. § 112, first paragraph. Removal of the 35 U.S.C. 112, first paragraph, rejection of the claims is believed to be in order and is respectfully requested.

Claim Rejections - 35 USC § 103

Claims 2-8, 13-15, 20-22 are rejected under 35 U.S.C. 103(a) as obvious over Nobufumi (JP 2000-012088) in view of Solomon (U.S. Patent No. 4,927,514), as evidenced by the glass transition point and melting point of polytetrafluoroethylene, retrieved by the Office on March 23, 2007, from the Internet at www.scientificpolymer.com/catalog/description.asp?QproductCode=203. Claim 17 is rejected under 35 U.S.C. 103(a) as obvious over Nobufumi in view of Solomon as evidenced by the glass transition point and melting point of polytetrafluoroethylene as applied to claim 2, further in view of Gan (U.S. 2002/0094480).

As noted above, claim 2 has been amended to include the limitation of claim 17.

Applicants understand the position of the Office to be that it would be obvious in view of Nobufumi and Solomon to heat treat a

negative electrode of Nobufumi, which uses PTFE as a binder, at a temperature of 280 to 350°C as disclosed in Solomon and that this temperature is higher than a glass transition temperature and lower than a decomposition temperature of the PTFE.

Applicants respectfully submit that a person of ordinary skill in the art would not be motivated to apply the teachings of Solomon relating to a platinum black air cathode to the negative electrode of the lithium secondary battery of Nobufumi. The properties desired of the platinum black air cathode for an electrolytic cell for producing ozone of Solomon in which an active layer comprising platinum black and PTFE are deposited on a support layer comprising a mixture of particulate carbon with hydrophobic polymer are not the same properties required for the negative electrode for a nonaqueous secondary battery of Nobufumi in which an active layer comprising a silicon-comtaining material, carbon and a binder are deposited on an electrolytic copper foil. Additionally, the Office has failed to satisfy its burden of providing proper evidence or reasoning showing that the electrodes of the respective references are so closely related that the conditions used to prepare the platinum black air cathode of Solomon would have been reasonably expected to have the same effects when applied to the negative

electrode of Nobufumi. Two references are not combinable merely because they both disclose negative electrodes.

Moreover, the Office has not shown how the proposed combination of Nobufumi and Solomon would result in a polyimide having the properties recited in claim 2. A position that the sintering conditions of Solomon, if applied to a negative electrode of Nobufumi where the binder is polyimide, would inherently result in a polyimide having the properties recited in claim 2 is inconsistent with the position of the Office taken in the 35 U.S.C. § 112, first paragraph, rejection.

For the above reasons, the Office has not shown a prima facie case of obviousness under 35 U.S.C. § 103(a) and removal of the 35 U.S.C. 103(a) rejections of the claims is also in order and is respectfully requested.

The foregoing is believed to be a complete and proper response to the Office Action dated June 7, 2007, and is believed to place this application in condition for allowance. If, however, minor issues remain that can be resolved by means of a telephone interview, the Examiner is respectfully requested to contact the undersigned attorney at the telephone number indicated below.

In the event that this paper is not considered to be timely filed, applicants hereby petition for an appropriate extension of time. The fee for any such extension may be charged to our Deposit Account No. 111833.

In the event any additional fees are required, please also charge our Deposit Account No. 111833.

Respectfully submitted,

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Attachment: Characteristics of commercially available binders and English translation of Table 4.1-2

4．ポリイミドの樹脂形状

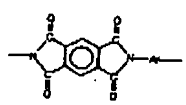
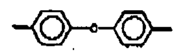
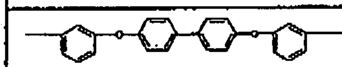
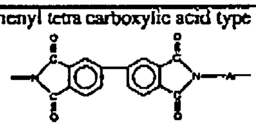
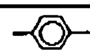
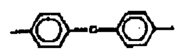
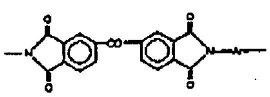
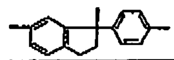
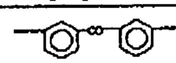
ポリイミドは多くの製品に使用されており、使用される段階での樹脂形状も多岐にわたる。中でも多いのはフィルムとワニスであるが、用途によりあらゆる樹脂形状のポリイミドが開発されている。

4．1 フィルム

A．代表的なポリイミドフィルム

ポリイミドフィルムの約70%はFPC(Flexible Printed Circuit Board)に使用され、残りが車両用モーターや産業用モーターのコイルの絶縁用フィルム、宇宙航空機器用や超電導機器用の電線被覆用フィルムなどに使用されている。近年、半導体実装用のTAB(Tape Automated Bonding)としても盛んに使用されるようになり一段と需要が伸びはじめた。代表的なポリイミドフィルムの分子構造とその商品名を表4.1-1に示す[1]。

表4.1-1　代表的なポリイミドフィルムの分子構造とその商品名[1]

Molecular structure of polyimide film	Ar	Tg (°C)	Trade name	Maker
Pyromellitic acid type 		420	KAPTON APICAL	Toray/du Pont Kaneka
		350	NOVAX	Mitsubishi Chemical
		250	REGURUS	Mitsui Toatsu
Biphenyl tetra carboxylic acid type 		500	UPILEX S	Ube
		290	UPILEX R	Ube
Benzophenone tetra carboxylic acid type 		320	XU216	Ciba-Geigy
		280	LARC-TPI	NASA

「Kapton」はDu Pont社により開発された世界最初のポリイミドフィルムであり、日本では東レ・デュポンが生産している。最近、寸法安定性の良いポリイミドフィルム「Kapton V.K.E」を上市[2]した。「Apical」は「Kapton」の特許が切れたと同時に鐘淵化学工業が生産を始めたもので、分子構造はほぼ同じである。最近、寸法安定性の良いポリイミドフィルム「Apical NPI」を上市[3]した。「Upilex」は宇部興産が独自開発したポリイミドフィルムで、「Kapton」とは分子構造が異なり、強度や弾性率は「Kapton」の２倍以上ある。このためフィルム厚みを半分にしても同等の性能が出せるため、電子部品材料の軽量化効果が大きく、特にTAB用途に需要が伸びている。「Novax」は三菱化学が開発したもので、主として垂直磁気記録の媒体用に使用

されている。「Regulus」は三井東圧化学(三井化学)が開発した熱可塑性のポリイミドフィルムで、各種回路基板などに使用されている[4 5 6]。ポリイミドフィルムの特性を、各種耐熱性フィルムのそれと比較して表4.1-2に示す[6 7]。

表4.1-2　高耐熱性フィルムの特性比較[6 7]

項　目	単 位	デュポン	宇部興産		鐘淵化学	三菱化成	日東電工		三菱樹脂	東燃石化	三井化学	住友化学	三井化学
		カプトン	ユーピレックス		アピカル	ノバックス	ニットミッド U		スペリオ UT	PAA	レグルス	スミカエクセル	ビクトレックス
		Hタイプ	R	S	AH		Film U	Film N	(PEI)	(ポリパラバン酸)		(PES)	(PEEK)
ラス転移温度	℃	(400)	285	>500	(400)	350	290	なし	216	290	250	225	143
収縮率(250℃, 30 min)	%	0.3	2h 0.18	2h 0.07	0.15	2h 0.16	0.11	0.10	230℃ 0.2	260℃ 0.35			
膨張率	$\times 10^{-5}$cm/cm/℃	2.0	1.5	0.8	2.1	1	2.0	2.3	4.9	4.2			
比熱	cal/g/℃	0.261	0.26	0.27	0.26				0.3~0.32				
張強さ (25℃)	kg/mm²	17.6	25	40	21.5	33	22.0	20.0	11	11.2	12	9	13
〃 (200℃)	〃	12.0	20	300℃ 22	12.0	19				3.9			
%伸長時応力 (25℃)	〃	9.1	12	26	10	21	12.0	7.5					
〃 (200℃)	〃	6.0	6	300℃ 9	6	10							
びび率 (25℃)	%	70	130	30	70	40	75	75	100	10	110	100	100
〃 (200℃)	〃	90	190	300℃ 48	92	55				5			
張弾性率 (25℃)	kg/mm²	302	380	900	350	700	310	280	300	211	310	260	300
〃 (200℃)	〃	183	210	300℃ 350	182	390				141			
裂き強さ(エルメンドルフ)	g/mm²	320	750	330	320	500					2100	900	1400
裂抵抗(グレーブ)	kg/mm²	20.1	40	23	19		20	20	18	20			
摩擦係数(フィルム/フィルム)		0.42	0.4	0.4	0.4	1				0.33			
縁耐力 (25℃)	kV/mm	276	276	268	275	296	320	320		220	280	260	250
〃 (200℃)	〃	220	280	268	210	250							
電率 (1kHz)		3.5	3.5	3.5	3.0	2.98	34	3.3	3.5	3.4	3.1	3.7	3.1
電正接 (1kHz)		0.003	0.0014	0.0013	0.0021	0.0007	0.0020	0.0020	0.0013	0.0040	0.0009	0.014	0.0047
積抵抗率	Ω・cm	10^{16}	10^{17}	10^{17}	5×10^{17}	4×10^{16}	10^{17}	10^{17}	10^{17}	5×10^{15}			
面抵抗率	Ω	10^{16}	$>10^{16}$	$>10^{16}$	1×10^{16}	5×10^{16}	$>10^{16}$	$>10^{16}$					
度	g/mm²	1.42	1.39	1.47	1.42	1.38	1.40	1.42	1.27	1.36	1.33	1.37	1.30
折率		1.78				1.75							
水率 (24h)	%	2.9	1.3	1.2	2.7	48h 2.4	1.3	2.1	0.25	125μm 2.8			
湿率 (50%/RH)	〃	1.3	1.0	0.8	1.2	0.98					0.24	0.53	0.13
度膨張率 (cm/cm/% RH)	$\times 10^{-5}$	2.2	2.2	1.1	2.1	1	2.0	2.2		4.7			

ポリイミドフィルムは優れた機械特性を有している。中でも、「Upilex」の引張強度は40kg/mm²と「Kapton」の約2倍で、軟鋼並の強度である。「Upilex」の引張弾性率も900kg/mm²と「Kapton」の約3倍で、フィルム厚みを半分にしても十分な腰を有している。ポリイミドフィルムの熱的特性は特に優れている。図4.1-1に、各種の耐熱性樹脂の重量減少率と温度の関係を示す[8]。「Upilex」が最高の耐熱性を示し、熱分解開始温度は520℃以上と高く、熱膨張係数は15ppmと小さい。

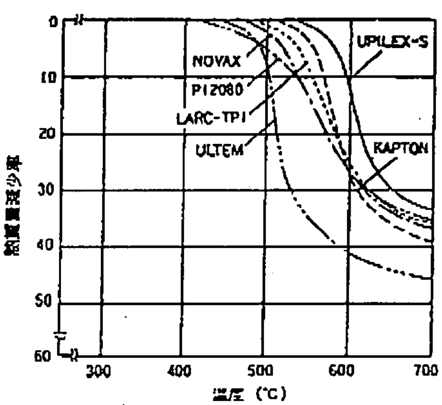


図4.1-1　各種の耐熱性樹脂の重量減少率と温度の関係[8]

ポリイミドフィルムの電気的特性も優れており、なかでも「Upilex」の誘電正接は低く、広い温度範囲、広い周波数域で安定である。化学的特性でも「Upilex」は耐薬品性、耐アルカリ性に優れている。吸湿特性[9]でも「Upilex」は優れており、イミド環を持っているにも拘わらず吸湿は小さく、吸湿による寸法変化はPET(Polyethylene terephthalate)並に小さい。

表4.4-1 主なポリイミド成形品の特性[1)]

	項目	単位	デュポン	日東電工	三菱化成		住友化学	EPL	東芝ケミカル	日本ポリイミド	東レ		測定法(基準) ASTM
			ベスペル SP-1	ニッドミッドM M-100	トーロン 4203L	PI-2080	スミカPAI M7000	ウルテム 1000	イミプロイ KIR-30	キネル 5514	TIポリマー TI-1500	TIポリマー TI-2500	
			ナチュラル	ナチュラル	TiO_2 3% PTFE 0.5%	ナチュラル	ナチュラル	ナチュラル	ナチュラル	GF50%	CF	CF	
			(切削加工品)		(PAI)		(PAI)	(PEI)	(マレイミド系)	(マレイミド系)	(熱硬化PAI)	(マレイミド系)	
熱的性質	ガラス転移温度	°C	(400)		(260)	310		217					
	熱膨張率	$\times10^{-5}$ cm/cm·°C	4.4	5.5	4.0	5.0	4.6	5.6	7	1.3	2.5	2.6	D696
	熱伝導度	kcal/m·h·°C	0.295	0.345	0.33		0.367	0.19		0.31	0.3	0.3	D621
	比熱	kcal/kg·°C	0.27										
	熱変形温度 (18.6 kg/cm²)	°C	−360		274	270−280		200		330	>300	>300	D648
機械的性質	引張強さ (23°C)	kg/cm²	875	990	1,900	1,200	950	1,070		450	850	670	D1706
	〃 (260°C)	〃	420	250°C 570	530	200°C 310	640			250°C 400	250°C 550	250°C 400	〃
	破断伸び (23°C)	%	7.5	7.3	12	10	6.5	60			1.2	0.5	〃
	〃 (260°C)	〃	7.0	250°C 7.0	22	–	12.5						〃
	曲げ強さ (23°C)	kg/cm²	1,330	1,400	2,160	1,970	1,600	1,480	960	1,500	1,400	1,400	D790
	〃 (260°C)	〃	770	250°C 18.1	760	200°C 350	900		200°C 870	250°C 1,250	250°C 900	250°C 720	〃
	曲げ弾性率 (23°C)	$\times10^{3}$ kg/cm²	31.5	31.1	46.7	35.2	42	33.7	35.7	140	103	66	〃
	〃 (260°C)	〃	17.5	18.1	30.3	290°C 11.3	25		200°C 28.5	200°C 105	250°C 70	250°C 8	〃
	圧縮強さ	kg/cm²	10%ひずみ 1,351	1,950	>3,100	2,000	2,600	1,430	2,060	2,400	2,200	2,700	D695
	圧縮弾性率	$\times10^{4}$ kg/cm²	24.5	24.2	31.6	20.7	27	29.6					〃
	衝撃強さ(アイゾット、ノッチ付き)	kg·cm/cm	8.1		13.8	7.9	2.0	5	2−3	30	4	3	D256
電気的性質	誘電率 (1 MHz)		3.55	1kHz 3.5	3.3	1kHz 3.42		1kHz 3.15	3.57	4.5	3.9	4.2	D150
	誘電正接 (1 MHz)		0.0034	〃 0.002	0.009	〃 0.0018		〃 0.0013	0.009	0.017	0.009	0.006	〃
	絶縁耐力	kV/mm	22		23.6			28		18	20	20	D149
	体積抵抗率	Ω·m	$10^{14}-10^{15}$	1.4×10^{13}	10^{14}		10^{14}	10^{17}	5×10^{14}	1×10^{14}	10^{14}	10^{14}	D257
	表面抵抗率	Ω	$10^{15}-10^{16}$		10^{15}		10^{16}				10^{14}	10^{13}	〃
その他	密度	g/cm³	1.43	1.41	1.40	1.4	1.41	1.27	1.30	1.7	1.73	1.62	
	硬さ (ロックウェル)		E45−48 M92−102		E91	E99	M117	M109		M118	M120	M119	D785
	吸水率 (24h)	%	0.24	48h 0.6	0.28		0.21	0.25		0.5	0.3	0.40	D570

B. 新しいポリイミド成形材料

デュポン社はピロメリット酸二無水物と4,4'-ジアミノジフェニルエーテルとからなるポリイミド成形材料「Vespel」を生産している。「Vespel」には、従来から販売している標準品の「SP-1」と新しく開発した「SCP-5000」がある。

「Vespel」の特徴は、①耐熱性が高く、大気中280℃、不活性ガス中400℃での連続使用が可能である、②引っ張り強度はPTFEの3倍、荷重変形はPTFEの1/70と、強靭で割れがたい、③耐摩耗性が優れ、PTFEよりも摩耗係数、摩耗量とも小さい、④耐薬品性に優れ、フッ酸洗浄が可能なので、常にクリーンに保てる、⑤真空下でも、高温下でも放出ガスが極めて少ない、などである。新しく開発した「ベスペルSCP-5000」の特徴は、表4.4-2に示すように、「ベスペルSP-1」に比較して、機械的強度や硬度、剛性が高く、また寸法安定性や耐摩耗性、耐薬品性、耐酸化性が優れることである[2)]。「Vespel」は半導体製造プロセス用の部材として有用であるが、これは先に述べた特徴の他に、純度が高く、デバイスに悪影響を与える不純物が極めて少ないことや、硬度がセラミックや石英よりも軟らかく、ウェハーやガラスにダメージを与えな

表4.4-2 「ベスペルSCP-5000」の特性[2)]

組成	SCP-5000	SP-1
	無充填	無充填
引張り強さ (kg / cm2) 23℃	1,360	878
260℃	534	422
引張り破断伸び (%) 23℃	4.0	7.5
260℃	14.0	7.0
圧縮強さ (kg/ cm2) 1% 歪み	441	253
10% 歪み	2095	1356
圧縮弾性率 (kg/ cm2)	36,300	24,600
表面硬度 (ロックウェルEスケール)	94	48 − 54
線膨張係数 (10E-5 cm/cm/℃)	3.8	5.0
吸水率 (%) 23℃ 24時間平衡	< 0.10	0.24
表面抵抗率 (Ω)	10 E 15	10 E 15
体積抵抗率 (Ω −cm)	10 E 16	10 E 16
誘電率 10 E4 Hz	3.44	3.64
10 E6 HZ	3.42	3.55
誘電正接 10 E4 Hz	0.0021	0.0036
10 E6 HZ	0.0012	0.0034

表4.1-2　高耐熱性フィルムの特性比較[6, 7]

項目	単位	デュポン	宇部興産		鐘淵化学	三菱化成	日東電工		三菱樹脂	東燃石化	三井化学	住友化学	三井化学
		カプトン	ユーピレックス		アピカル	ノバックス	ニットミッド U		スペリオ UT	PAA	レグルス	スミカエクセル	ビクトレックス
		H タイプ	R	S	AH		Film U	Film N	(PEtI)	(ポリパラバン酸)		(PES)	(PEEK)
ガラス転移温度	℃	(400)	285	>500	(400)	350	290	なし	216	290	250	225	143
熱収縮率(250℃, 30 min)	%	0.3	2h 0.18	2h 0.07	0.15	2h 0.16	0.11	0.10	230℃ 0.2	260℃ 0.35			
線膨張率	$\times 10^{-5}$cm/cm/℃	2.0	1.5	0.8	2.1	1	2.0	2.3	4.9	4.2			
比熱	cal/g/℃	0.261	0.26	0.27	0.26				0.3〜0.32				
引張強さ (25℃)	kg/mm²	17.6	25	40	21.5	33	22.0	20.0	11	11.2	12	9	13
〃 (200℃)	〃	12.0	20	300℃ 22	12.0	19				3.9			
5%伸長時応力 (25℃)	〃	9.1	12	26	10	21	12.0	7.5					
〃 (200℃)	〃	6.0	6	300℃ 9	6	10							
伸び率 (25℃)	%	70	130	30	70	40	75	75	100	10	110	100	100
〃 (200℃)	〃	90	190	300℃ 48	92	55				5			
引張弾性率 (25℃)	kg/mm²	302	380	900	350	700	310	280	300	211	310	260	300
〃 (200℃)	〃	183	210	300℃ 350	182	390				141			
引裂き強さ(エルメンドルフ)	g/mm²	320	750	330	320	500					2100	900	1400
端裂抵抗(グレーブ)	kg/mm²	20.1	40	23	19		20	20	18	20			
動摩擦係数(フィルム/フィルム)		0.42	0.4	0.4	0.4	1				0.33			
絶縁耐力 (25℃)	kV/mm	276	276	268	275	296	320	320		220	280	260	250
〃 (200℃)	〃	220	280	268	210	250							
誘電率 (1kHz)		3.5	3.5	3.5	3.0	2.98	34	3.3	3.5	3.4	3.1	3.7	3.1
誘電正接 (1kHz)		0.003	0.0014	0.0013	0.0021	0.0007	0.0020	0.0020	0.0013	0.0040	0.0009	0.014	0.0047
体積抵抗率	Ω·cm	10^{18}	10^{17}	10^{17}	5×10^{17}	4×10^{16}	10^{17}	10^{17}	10^{17}	5×10^{16}			
表面抵抗率	Ω	10^{15}	$>10^{15}$	$>10^{15}$	1×10^{18}	5×10^{16}	$>10^{16}$	$>10^{15}$					
密度	g/mm²	1.42	1.39	1.47	1.42	1.38	1.40	1.42	1.27	1.36	1.33	1.37	1.30
屈折率		1.78				1.75							
吸水率 (24h)	%	2.9	1.3	1.2	2.7	48h 2.4	1.3	2.1	0.25	125μm 2.8			
吸湿率 (50%/RH)	〃	1.3	1.0	0.8	1.2	0.98					0.24	0.53	0.13
湿度膨張率 (cm/cm/% RH)	$\times 10^{-5}$	2.2	2.2	1.1	2.1	1	2.0	2.2		4.7			

表4.4-1 主なポリイミド成形品の特性[1)]

	項目	単位	デュポン	日東電工	三菱化成	三菱化成	住友化学	EPL	東芝ケミカル	日本ポリイミド	東レ	東レ
			ベスペル SP-1	ニッドミッドM M-100	トーロン 4203L	PI-2080	スミカPAI M7000	ウルテム 1000	イミダロイ KIR-30	キネル 5514	TIポリマー TI-1500	TIポリマー TI-2500
			ナチュラル	ナチュラル	TiO_2 3% PTFE 0.5%	ナチュラル	ナチュラル	ナチュラル	ナチュラル	GF 50%	GF	GF
			(切削加工品)		(PAI)		(PAI)	(PEI)	(マレイミド系)	(マレイミド系)	(熱硬化PAI)	(マレイミド系)
熱的性質	ガラス転位温度	℃	(400)		(260)	310		217				
	熱膨張率	$\times 10^{-5}$cm/cm·℃	4.4	5.5	4.0	5.0	4.6	5.6	7	1.3	2.5	2.6
	熱伝導度	kcal/m·h·℃	0.295	0.345	0.33		0.367	0.19		0.31	0.3	0.3
	比熱	kcal/kg·℃	0.27									
	熱変形温度 (18.6 kg/cm²)	℃	~360		274	270~280		200		330	>300	>300
機械的性質	引張強さ (23℃)	kg/cm²	875	990	1,900	1,200	950	1,070		450	850	670
	〃 (260℃)	〃	420	250℃ 570	530	290℃ 310	640			250℃ 400	250℃ 550	250℃ 400
	破断伸び (23℃)	%	7.5	7.3	12	10	6.5	60			1.2	0.5
	〃 (260℃)	〃	7.0	250℃ 7.0	22	—	12.5					
	曲げ強さ (23℃)	kg/cm²	1,330	1,400	2,160	1,970	1,690	1,480	960	1,500	1,400	1,400
	〃 (260℃)	〃	770	250℃ 18.1	760	290℃ 350	900		200℃ 870	250℃ 1,250	250℃ 900	250℃ 720
	曲げ弾性率 (23℃)	$\times 10^3$kg/cm²	31.5	31.1	46.7	35.2	42	33.7	35.7	140	103	66
	〃 (260℃)	〃	17.5	18.1	30.3	290℃ 11.3	25		200℃ 28.5	200℃ 105	250℃ 70	250℃ 8
	圧縮強さ	kg/cm²	10%ひずみ 1,351	1,950	>3,100	2,000	2,690	1,430	2,080	2,400	2,200	2,700
	圧縮弾性率	$\times 10^3$kg/cm²	24.5	24.2	31.6	20.7	27	29.6				
	衝撃強さ (アイゾット, ノッチ付き)	kg·cm/cm	8.1		13.8	7.9	2.0	5	2~3	30	4	2
電気的性質	誘電率 (1 MHz)		3.55	1 kHz 3.5	3.3	1 kHz 3.42		1 kHz 3.15	3.57	4.5	3.9	4.2
	誘電正接 (1 MHz)		0.0034	〃 0.002	0.009	〃 0.0018		〃 0.0013	0.009	0.017	0.009	0.006
	絶縁耐力	kV/mm	22		23.6			28		18	20	20
	体積抵抗率	Ω·m	10^{14}~10^{16}	1.4×10^{11}	10^{13}		10^{15}	10^{17}	5×10^{14}	1×10^{14}	10^{15}	10^{11}
	表面抵抗率	Ω	10^{13}~10^{16}		10^{15}		10^{15}				10^{14}	10^{15}
その他	密度	g/cm³	1.43	1.41	1.40	1.4	1.41	1.27	1.30	1.7	1.73	1.62
	硬さ (ロックウェル)		E 45~48 M 92~102		E 91	E 99	M 117	M 109		M 118	M 120	M 119
	吸水率 (24 h)	%	0.24	48 h 0.6	0.28		0.21	0.25		0.5	0.3	0.40

Table 4. 1-2 Comparison of Characteristics of Highly Heat Resistant Films [6,7]

Item	Unit	Du Pont	Ube Machinery		KANEKA	Mitsubishi Chemical	Nitto Denko		Mitsubishi Plastics	Tonen General	Mitsui Chemical	Sumitomo Chemical	Mitsui Chemical
		Kapton	Upilex		Apical	Nobax	Nitto Mid U		Superio UT	PAA	Reglus	Sumika Excel	Pictrex
		H Type	R	S	AH		Film U	Film N	(PEtI)	(Polyparabanic Acid)		(PES)	(PEEK)
Glass-Transition Temperature	℃	(400)	285	>500	(400)	350	290	No	216	290	250	225	143
Coefficient of Heat Shrinkage (250℃, 30 min)	%	0.3	2h 0.18	2h 0.07	0.15	2h 0.16	0.11	0.10	230℃ 0.2	260℃ 0.35			
Coefficient of Linear Expansion	$\times 10^{-5}$ cm/cm/℃	2.0	1.5	0.8	2.1	1	2.0	2.3	4.9	4.2			
Specific Heat	cal/g/℃	0.261	0.26	0.27	0.26				0.3~0.32				
Tensile Strength (25℃)	kg/mm²	17.6	25	40	21.5	33	22.0	20.0	11	11.2	12	9	13
Tensile Strength (200℃)	〃	12.0	20	300℃ 22	12.0	19				3.9			
Stress at 5% Elongation (25℃)	〃	9.1	12	26	10	21	12.0	7.5					
Stress at 5% Elongation (200℃)	〃	6.0	6	300℃ 9	6	10							
Coefficient of Extension (25℃)	%	70	130	30	70	40	75	75	100	10	110	100	100
Coefficient of Extension (200℃)	〃	90	190	300℃ 48	92	55				5			
Coefficient of Elasticity (25℃)	kg/mm²	302	380	900	350	700	310	280	300	211	310	260	300
Coefficient of Elasticity (200℃)	〃	183	210	300℃ 350	182	390				141			
Tearing Strength(Elmendorf)	g/mm²	320	750	330	320	500					2100	900	1400
End Tear Drag (Graves)	kg/mm²	20.1	40	23	19		20	20	18	20			
Coefficient of Dynamic Friction (Film / Film)		0.42	0.4	0.4	0.4	1				0.33			

Table 4. 4-1 Characteristics of Major Polyimide Moldings [1]

Item	Unit	Du Pont	Nitto Denko	Mitsubishi Chemical		Sumitomo Chemical	EPL	Toshiba Chemical	Nippon Polyimide	Toray	
										TI Polymer	
		VESPEL SP-1	Nitto Mid M M-100	Tolon 4203 L	PI-2080	Sumika PAI M 7000	ULTEM 1000	Imidaroy KIR-30	Kinel 5514	TI-1500	TI-2500
		Natural	Natural	TiO_2 3 % PTFE 0.5 %	Natural	Natural	Natural	Natural	GF 50 %	GF	GF
		(Cutting Operated)		(PAI)		(PAI)	(PEtI)	(Maleimide Type)	(Maleimide Type)	(Thermo-setting PAI)	(Maleimide Type)
Glass-Transition Temperature	°C	(400)		(260)	310		217				
Coefficient of Thermal Expansion	$\times 10^{-5}$ cm/cm·°C	4.4	5.5	4.0	5.0	4.6	5.6	7	1.3	2.5	2.6
Heat Conductivity	kcal/m·h·°C	0.295	0.345	0.33		0.367	0.19		0.31	0.3	0.3
Specific Heat	kcal/kg·°C	0.27									
Heat Distortion Temperature (18.6kg/cm²)	°C	~360		274	270~280		200		330	>300	>300
Tensile Strength (23°C)	kg/cm²	875	990	1,900	1,200	950	1,070		450	850	670
Tensile Strength (260°C)	〃	420	250°C 570	530	290°C 310	640			250°C 400	250°C 550	250°C 400
Elongation at Break (23°C)	%	7.5	7.3	12	10	6.5	60			1.2	0.5
Elongation at Break (260°C)	〃	7.0	250°C 7.0	22	—	12.5					
Bending Strength (23°C)	kg/cm²	1,330	1,400	2,160	1,970	1,690	1,480	960	1,500	1,400	1,400
Bending Strength (260°C)	〃	770	250°C 18.1	760	290°C 350	900		200°C 870	250°C 1,250	250°C 900	250°C 720
Bending Modulus (23°C)	$\times 10^3$ kg/cm²	31.5	31.1	46.7	35.2	42	33.7	35.7	140	103	66
Bending Modulus (260°C)	〃	17.5	18.1	30.3	290°C 11.3	25		200°C 28.5	200°C 105	250°C 70	250°C 8
Compression Strength	kg/cm²	10 % Strain 1,351	1,950	>3,100	2,000	2,690	1,430	2,080	2,400	2,200	2,700
Compression Modulus	$\times 10^3$ kg/cm²	24.5	24.2	31.6	20.7	27	29.6				
Impact Strengrh (Izod, Notched)	kg·cm/cm	8.1		13.8	7.9	2.0	5	2~3	30	4	2